The housing sector as a driver for sustainability transitions in Skellefteå by 2050

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1 Executive summary

Skellefteå 2050, an inclusive city that sustainably grows with you. This formulated vision, addressing the sustainability transition in Skellefteå, encapsulates growth in two ways: the literal population growth as well as the personal growth of its inhabitants. To reach this vision, the housing sector was identified as a crucial component and therefore became the focus of the study. Finding accommodation for the people moving to Skellefteå can be viewed as a short term problem but if the long term approach is not taken today, the risk of lock-in into sub-optimal systems exists.

Three different solutions were identified, with varying possibility of leading to this vision being realised. The final recommended solution is a combination of two of these three solutions. It entails a market with multiple competitors, building co-living spaces, with machines run on electricity. The material used for building construction is wood or hempcrete and the co-living spaces are connected to peer-to-peer network that run on renewable electricity. Related to this solution, five experiments have been identified that should be implemented as soon as possible to investigate the feasibility of the solutions. The experiments are as follows: creating a pilot project for a peer-to peer energy system in a neighborhood, constructing one apartment building made of wood and one of hempcrete, creating a co-living space to be inhabited by new Northvolt employees, and building a villa with the use of construction machines run on electricity.

It is difficult to understand whether the vision has been reached or not, therefore criteria, covering the three pillars of sustainability, are used to assess the progress towards the vision. The criteria are connected to indicators, which is a way of quantifying the criteria. The criteria (and the related indicator in brackets) are: availability of housing (number of temporary housings and housing shortage), affordable housing (house-price-to-income ratio and the rent-price-to-income ratio), comfortable housing (persons/m2), energy-efficient housing (energy demand in kWh/m2), and the integration factor (survey of citizens). The idea is that Skellefteå municipality can, on a regular basis, use these indicators to understand whether the development is going in the right direction or not.

In addition to the experiments, a pathway for how to reach the solution is presented. The suggestions were divided into three categories based on cultural, structural or institutional, and technological change. The timeframe for the ideas are 2022, 2030, and 2050, with a natural emphasis on the two former years, meaning most of the decisions taken to reach the vision will occur in the upcoming years. Events and information campaigns, with stakeholder co-operation, are an important aspect to explain the different steps being taken to reach the vision for the citizens of Skellefteå.

The limitations of this project should be noted for any stakeholder reading it. The method used in the study, modular participatory backcasting is reliant on stakeholder participation. However, contact was only had with the municipality, limiting the knowledge for how other stakeholders view the identified problem. It is entirely possible that some solution proposed would be deemed unfeasible had a particular stakeholder been involved. The recommendation is therefore to further explore the solutions presented to understand how relevant they are for the situation in Skellefteå.

2 Introduction

Cities are responsible for 70% of the worlds greenhouse gas emissions despite accounting for only 3% of the worlds surface area and therefore play a key role in the transition to a world that operates within the planetary boundaries (UnitedNations n.d.[b]). The emissions are mainly related to the heating and electricity, building, and transportation sector (UnitedNations n.d.[a]). Different initiatives, such as Cities 2030, C40, and Viable Cities (Cities2030 n.d.; C40Cities 2022). ViableCities (2022b) have been launched as a response to this pressing task. The latter initiative was initiated in Sweden 2017, with the mission of making Swedish cities climate neutral by 2030. It is intended to act as a catalyst for the cooperation between municipalities, academia, research institutes, the private sector, and citizens (ViableCities 2022c).

Cities in the country have applied to be a part of the program and based on certain criteria have been selected. As of 2022, 23 cities representing 40% of the population are part of the program. One of the cities that, together with 13 others, joined in the second phase of the program was Skellefteå (ViableCities 2022a). The city of Skellefteå is in a unique situation. Because of the establishment of the battery company Northvolt, 3000 jobs are projected to be created in the upcoming years. This would lead to population growth, and forecasts made by the consulting agency Ramboll have provided three possible scenarios for population growth in the municipality by 2030. The lowest scenario estimates an increase of around 2000, the middle scenario an increase of around 7000, and the highest scenario an increase of around 18000 people (Norran 2021). Based on the information provided from the municipality, the middle and high scenarios are deemed most likely.

Skellefteå therefore faces a two-fold challenge; becoming a climate neutral city by 2030 while at the same time dealing with a, for the city, unprecedented population growth (SkellefteåKommun 2021d). There are many aspects that need to be considered when planning for an increase in population. The demand on key societal institutions, such as education, healthcare, transport, energy, and accommodation, all increase. The latter can be seen as one of the first hurdles for people planning on moving to Skellefteå. It is therefore of particular interest to investigate what the long term vision for the building sector could be with the goals of Viable Cities and Skellefteå Municipality in mind.

2.1 Aim and Objectives

The aim of the study is to find pathways and solutions for sustainability transitions in Skellefteå by 2050, focusing on the housing sector and using the modular participatory backcasting framework.

To reach this aim, the following main objectives should be met

- Identifying challenges faced by Skellefteå municipality and investigate the current state of the of the socio-technical system
- Identify relevant stakeholders and their needs
- Create a vision that states a desirable future for Skellefteå by 2050
- Identify possible solutions to be implemented and the pathways necessary for the vision to be realized

3 Methods

In this section the method used to address the problem is presented.

3.1 Data collection

The information found in this study has been gathered through a literature review and through interviews/personal contact with Skellefteå municipality. The research literature that was used was accessed through KTHs online library while non-scientific articles were accessed through Google. News paper articles and Skellefteå municipality's website were important sources of information.

3.2 The modular Participatory Backcasting

Backcasting is a method where a desired future is stated and a pathway in which one gets to that future is developed. It is developed by asking the question: What can be done today to get to that specific place in the stated time frame? The tool is useful when the stated problem involves a complex system that is currently showing trends that are not aligned with a declared vision. Furthermore, it works particularly well when applied to systems where sustainability is an important factor (Holmberg and Robèrt 2000) .

Modular participatory backcasting (mPB) can be seen as a branch of backcasting. It was developed by a team of researchers at Royal Institute of Technology KTH who recognized that stakeholders should be involved when planing for long-term changes in a system that they are a part of. By letting stakeholders participate in the process, a joint future vision can be created, which ideally should increase the probability of success. (Kordas et al. n.d.[d]).

The mPB consists of 13 modules: problem orientation, system boundaries, current situation, stakeholder analysis, needs and function, vision, criteria, drivers, solutions, solution testing, pathway, action plan, and follow ups. In this particular application of the framework, the last two modules were made into one module where five experiments to be initiated immediately in order to reach the vision were chosen. Although the modules are intended to be done in the order they are, the process is an iterative one, meaning realisations in one module may lead to the conclusion that something in a previous module needs to be changed.

4 Results

This section focuses on the outcomes of the modules presented by Kordas et al. (n.d.[d]).

4.1 Problem orientation

Skellefteå municipality is expecting 16 000 new residents by 2030 on top of its normal migration and the population growth is still forecasted to continue after that (SkellefteåKommun 2021d). This presents a risk for the city if the issue is not considered comprehensively beforehand. To name a few examples, the municipality needs to establish new housing projects, increase energy production as well as develop its transportation sector. Moreover, all of this should be done in an inclusive and sustainable way.

Different stakeholders view the challenges related to the rapidly growing population differently. The municipality specifies challenges in four different areas: housing, education, employment and travel infrastructure. The challenge of the housing sector is to meet the increasing demand while maintaining and building trust, security and inclusion. The education sector has to offer equal education to an increasing number of students with different backgrounds. Because of the immigration, the demographic of the city is likely to change, with more people from foreign countries of different ages, which means that the labour market has to be inclusive to achieve a socially sustainable growth. Furthermore, it is crucial for Skellefteå to have sufficient connections to the rest of the world to be an attractive and international hub (SkellefteåKommun n.d.).

The public transport, consisting of Skellefteå buss, is also a closely connected stakeholder in the challenge of increasing population. It needs to increase capacity without negative environmental impact and increasing emissions (SkellefteåKommun 2020). Skellefteå Kraft, the municipality owned energy company, states that they have to prepare for six-times larger energy consumption by 2030. This is partially caused by Northvolt, a battery manufacturer with a site in Skellefteå, and some traditional industries switching from conventional fuels to electricity. The energy company has to investigate the possibility to increase its energy production with hydro power and also alternative solutions to secure sufficient capacity. Furthermore, overcoming the challenge requires expanding the grid quickly, which also means that a more efficient permit process is needed (Holmström 2021).

The residents' point of view must also be taken into account when making changes in the municipality. Their local voices are represented through the three major political parties in Skellefteå. Socialdemokraterna states that their target is to develop the municipality in a way that considers changes in the supply of skills, housing construction and infrastructure (Socialdemokraterna 2021). Moderaterna highlights a need for political reforms to strengthen the population growth and demands investments in schools, housing construction and infrastructure (Moderaterna 2021). The third most popular party, Centerpartiet, states that comprehensive planning is needed for the municipality to remain functional, including planning of schools, roads and water system. It should be noted that despite the obstacles, all the parties have a policy stating that the increasing population is more an opportunity than a challenge. (Centerpartiet 2022).

Looking at the future of Skellefteå from a sustainability perspective, the main challenges include the integration of new population, sufficient renewable energy production, equal and adequate housing opportunities, quality education and healthcare, inclusive and sustainable industrialization, accessible transport system and overall inclusive city for everyone (UnitedNations n.d.[c]). In addition, the choices that the planners make regarding housing types, location of development, transportation solutions and land use, affect the chances to achieve sustainable development (Næss 2001).

As many of the stakeholders highlight, the housing sector faces a challenging task to provide a lot of new accommodations. In numbers, this means that Skellefteå needs 9 000 new homes to meet the housing demand by 2030 (SkellefteåKommun 2021c). Thus, the socio-technical system investigated in this essay is the housing sector. The relevant stakeholders examined in module 4 are citizens, construction companies, the municipality, Skellefteå Kraft and Northvolt.

The new EU Fit for 55 package states that all new buildings from 2030 must be zero-emission and older ones have to be renovated to correspond to EU-level efficiency standards. The end goal is to achieve a zero-emission building stock by 2050 (EuropeanParliament 2022a). Skellefteå has plans to reach this target by using wood as a building material as it produces less CO2 emissions than conventionally used materials such as steel and concrete (SkellefteåKommun 2014). However, the EU has adopted the New EU Forest Strategy for 2030, which focuses on strengthening forest protection and restoration, enhancing sustainable forest management, and improving the monitoring and effective planning of forests in the EU (EuropeanParliament 2022b). To conclude, the housing sector is under pressure which makes this a problem that has to be solved quickly.

4.2 System boundaries

In order to describe the system boundaries of the socio-technical system associated with the given problem, a life-cycle approach was employed. "Life Cycle Thinking (LCT) is about going beyond the traditional focus on production site and manufacturing processes to include environmental, social and economic impacts of a product over its entire life cycle" (LCI 2022). In the given case, it is possible to employ the life-cycle approach when examining the housing sector as a socio-technical system, considering construction, maintenance, and demolition of the buildings.

Due to the frequently underestimated impact, all three phases were considered essential for the system boundaries, especially the construction phase. As stated by IVA (2014), in Sweden, the total impact from construction processes of houses is estimated at around 0.3–0.5 Mtons CO2 per year.

Lastly, it is always important to evaluate the end-of-life when employing LCT. Therefore, it was also crucial to consider the demolition stage in the system boundaries (Brière et al. 2015).

Another crucial step towards identifying system boundaries is distinguishing the internal part of the system and the external environment. Actors and institutions were already pointed out in 4.1. Nevertheless, it is worth pointing out the interrelation between them. The municipality owns the power company (Skellefteå Kraft); therefore, the latter is subordinate to the former. This kind of hierarchy does not apply to privately-owned companies, such as construction companies or Northvolt; nevertheless, the municipality is still more powerful. Regarding citizens, they are subordinate to both the municipality and privately-owned companies.

While all the parties mentioned above can be entirely identified as internal parts of the system boundaries, Campus Skellefteå is a case in itself; it can be seen both as an inner part of the system or an external environment because it is not an independent university but a branch of Umeå University and Luleå Technical University (SkellefteåKommun 2021f). In the socio-technical system under consideration, the university will be evaluated as an internal part.

The external environment can be described as the combination of building construction regulations, cultural trends and technology evolution. When referring to regulations, both the Swedish and EU's regulations will be considered.

To summarize, a bullet point list is presented that concisely highlights the system boundaries.

- Sectorial: housing sector
- Spacial boundaries: Skellefteå municipality. Administrative and geographical boundaries can collide, but to some extent, the administrative boundary can be zoomed out (whether being Sweden or EU more in general)
- Timescale: the timescale is longer than 2050 because the chosen sector focuses on a longer period (30/50 years)
- Social components (actors): Campus Skellefteå, citizens, construction companies, municipality, power company, Northvolt
- Technical components: machine for building, electricity system, heating system, water supply system

4.3 Current situation analysis

Understanding the current housing situation in Skellefteå is important because it casts a light on the current trends, both positive and negative, indicating where the development is heading. Helena Renström, marketing manager of Skellefteå Municipality says the housing issue is one of the two main challenges for the municipality the coming years (Israelsson 2021). Lars Hedqvist, planing manager at Skellefteå Municipality says that the expectation is that 1000 homes will be build every year for the coming five years (Lindkvist 2021).

All sorts of different houses are currently being built; temporary houses, rentals, row houses, condominiums, and villas. The willingness to invest, both from private citizens and construction companies is large, according to the municipality's land and exploitation manager Patrik Larsen. A plethora of private construction companies are along with Skebo, a municipality owned construction company, involved in the process (SkellefteåKommun 2021b).

In 2014, the politicians in charge of Skebo took the controversial decision to sell 1000 apartments to the private construction company Heimstaden. It was important to get a new actor in the local housing market, according to Skebo CEO Åsa Andersson, and the money gained from the sale was used to build hundreds of apartments. In 2017, Riksbyggen, Lindbäcks and Heimstaden joined Skebo in creating a new company called Byggrätt Norr, who have signed up for making 1000 apartments by 2024. SBB, Samhällsbyggnadsbolaget, have announced efforts to build a total of 1500 apartments in the municipality (Israelsson 2021).

Northvolt is hiring around 100 people every month and finding accommodation for them has proven to be difficult (Samuelsson 2021c). Mengxue Nie, a new Northvolt employee from China, has had to live in temporary housing provided by her employer since she arrived in the city (Samuelsson 2021a). To help Northvolt, Skellefteå municipality have launched a campaign asking the citizens of Skellefteå for spare rooms, cabins, or apartments that they can rent out to the newcomers: 36 000 households have been contacted and asked to be a "Housing-Hero" (Samuelsson 2021c). Because of the shortage of accommodations for Northvolts employees, the company is currently looking at solutions outside the municipality, in Norsjö, Robertsfors, and Piteå, arguing that a one hour commute is feasible. The person responsible for housing at the company, Anders Thor, thinks it will take at least one year before things turn around, and accommodation becomes less of an issue for their employees. At the moment, the company is renting summer houses from local citizens(Öhlund 2021a). They are also searching for construction companies who can build 50-100 so called " Northvolt-villas" a year (Bergström 2022).

The price of an apartment in Skellefteå has increased by 346% the last ten years. The Covid

19-pandemic led to increased housing prices all over the country, but the highest increase in price was in Skellefteå (Larsson 2021). A trend can also be seen in citizens who are renting out their villas and apartments and moving out to their summer houses. Depending on the size of the accommodation, the rents are going for anywhere between 20 000 - 70 000 kr a month. Single beds in apartments are rented at a price of 4 000 kr a month according to (anonymous) citizens when talking to SVT (Öhlund 2021b).

The interest for rental apartments has gone up and during the last five years the housing queue has increased by 10 000 people, reaching 38 000 as of fall 2021. Furthermore, more and more people are looking to settle down outside of the city (Samuelsson 2021b). Finding accommodation as a student in Skellefteå is easy however, according to a report done by Sveriges förenade studentkårer (Swedens Student Union). A housing guarantee is in place and it is expected that all students have accommodation before the semester starts, which places Skellefteå in the top tier for student accommodations in Sweden. Students pay a rent of around 2 200 - 3 300 kr, with a 10 month rent (Skebo 2019).

To summarize, the housing situation in Skellefteå appears to be strained. The influx of people seems to outpace the lead time for construction, leading to drastic measures such as calling for citizens to be ”Housing-Heros” or requiring the battery company Northvolt to act as a housing broker.

4.4 Stakeholder analysis

According to the mPB manual (Kordas et al. n.d.[b]), stakeholders can be defined as either individuals or organizations that have the ability to influence an issue – either a problem or a decision to be made – or to be influenced by said issue. The analysis of the stakeholders entails several key processes which include listing, classifying, and assessing how much influence said stakeholders possess. It also includes an examination of the power possessed by the stakeholders, the interests they have, their respective roles and any other characteristics of the involved actors that can be deemed as valuable to the case at hand.

With the basis of the stakeholder analysis established, an incremental approach to the analysis shall be followed to provide clarity on the motivation and rationale.

Citizens – According to Avelino and Wittmayer (2016), the community (citizens) contains families, households, neighbours, friends, etc. Furthermore, based on an analysis of the Welfare Mix carried out by (ibid.) it was concluded that the community can be classified as private, informal, and non-profit. In this case the ‘informal’ speaks to the nature of the power they possess. In this analysis, both current and future citizens will be considered. Taking into account that citizens are individuals with different opinions, interests, and background, they can not be considered as a homogeneous group (Vanolo 2016). Therefore, considering these aspects, a range has been created that goes from citizens who are actively involved in city affairs to citizens who are not (termed ‘Que Sera Sera Citizens’). In the context of housing the citizens will be significantly impacted by any and all decisions that are made.

Municipality Politicians - Municipality politicians have a significant role in the operation of a municipality. They have many areas of responsibility concerning the municipality, such as social development goals, budget, and services provided for the residents and businesses. Politicians’ actions are thus affecting the “Sustainability transitions in Skellefteå” project. However, they are also members of various boards and committees where they can bring proposals for changes and improvements in the municipality, and in this context the sustainability project as well. All of this

means that the politicians have formal power as they can directly influence this project (Smith, Stirling, and Berkhout 2005; SverigesKommuner 2021; Kungsbacka n.d.). Therefore, with regards to housing, politicians will be involved in more than one way due to their formal power and their involvement with various boards and committees.

Northvolt - Northvolt is one of the major stakeholders considered in the socio-technical system under study. According to Avelino and Wittmayer (2016), a private firm like Northvolt can be characterized as formal, private and for-profit. Furthermore, exploring the sphere of social sustainability, Northvolt's establishment will generate around 3000 jobs when the Skellefteå factory is fully expanded in 2025 (Skellefteå kommun 2022). This creation of jobs and its subsequent attraction of talent is what links Northvolt to the particular problem that is being targeted by the study. As seen in Section 4.3, Northvolt is actively involved in the housing situation as they are committed to providing housing for part of its employees.

Building Companies – One publicly owned building company, Skebo. Politicians are in charge of decisions.

Private Companies - These companies are important stakeholders that must be considered concerning the housing situation in the city of Skellefteå. Being private firms, as explained by Avelino and Wittmayer (2016), these companies can be characterized as formal, private, and for-profit. These are the companies that are eventually going to be the ones that are at responsible for the actual realization of any and all housing solutions that will be proposed in the city of Skellefteå.

Campus Skellefteå- Both Luleå and Umeå university courses are taught here (SkellefteåKommun 2021f). As mentioned in the current situation, the accommodation for students in the city is working, but with an influx of new people it is likely that they will be interested in the housing situation and actively looking for housing solutions that will be feasible for its' students. Their interests would lie in providing housing that is not just easily accessible to the university premises but also economically viable for the students and the universities as well.

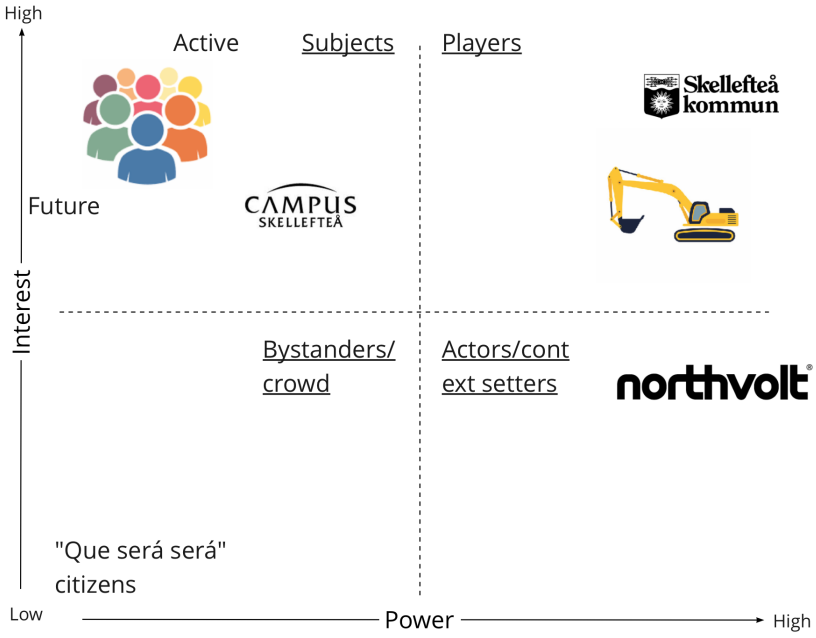

Figure 1: Power-interest analysis

4.5 Needs and system functions

The main need that has been identified in this study, related to the challenges of Skellefteå municipality, is the need of a place to live. This is mainly thought to be a concern for the people who are moving to Skellefteå in the coming decade. The current inhabitants already have somewhere to live and therefore don't share this specific need. The need of shelter can be explained through "sub-needs", exemplified by the American psychologist Abraham Maslow in his hierarchy of needs model (Cherry 2022).

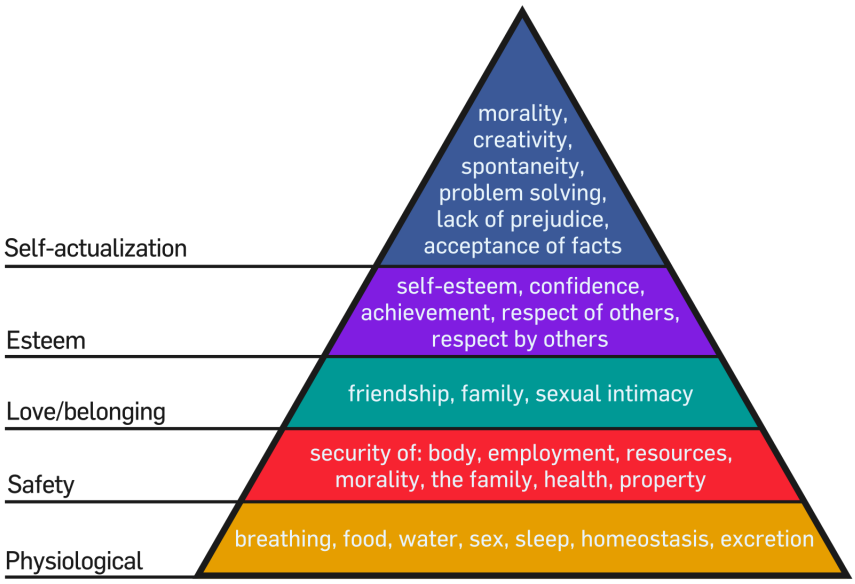

Figure 2: Maslow's hierarchy of needs (Wikimedia 2012).

Each step of Maslow's hierarchy of needs (Fig. 2) builds on the previous one, meaning one can only reach the next step if all the criteria in the current step are met. Whether this is strictly true or not can be debated, but the model provides a suitable starting point for a discussion on the needs of the individuals of Skellefteå.

The focus of this study, housing, acts as the function to achieve needs on several levels of the hierarchy. In the physiological step, it can be argued that proper housing provides peoples need of sleep, water, and excretion, through the functions imbedded in housing (beds, pipes, and toilets). Housing also helps in the next step, safety, providing safety for the body, the family, and your health.

As the building of houses progresses, and more and more people find a place to stay, the needs of the people who have recently moved in will align more with that of the current inhabitants. The needs will likely shift to more "luxurious" needs related to housing. For example, there could be a need for more green areas, need for integration, or need for environmentally friendly living. The reason for this can also be found through Maslow's model: when your basic needs are fulfilled, more extravagant needs are sought after. Because the current need of housing is so "strong", the risk of sidestepping or ignoring the possible needs of the future citizens is apparent. Buildings have a long life cycle and if the future needs are not taken into account, the risk of lock-in into sub-optimal systems exists. However, Skellefteå municipality have exhaustive lists of their sustainable building

practice and if these are followed, the risk is significantly lowered (SkellefteåKommun 2021a).

4.6 Future vision

As stated in the mPB, the vision should be an amalgamation of a strong guiding power along with a desirable future for the said system within the confines of a specified time frame. With the basis of the vision established, an incremental approach to the formation of the vision shall be followed to provide clarity on the motivation and rationale for the ultimate vision that has been formulated.

First and foremost, the time frame for said vision should be identified and clearly demarcated in order to ensure that the vision can be attainable. 2050 provides a realistic time frame wherein once backcasted from, provides enough room for the impacts to be visible. Had a shorter timescale been chosen, this might not have been the case.

Moving on from the time frame, focus can now be shifted to what is entailed by a 'desirable' future. With regards to this case, there is a requirement of growth from the point of view of the city. Growth in this sense can be viewed in two ways: the need for an increased number of houses to accommodate the influx of new people, and the growth of the people living in the city as they transition into a new way of living. According to Dempsey et al. (2011) socially sustainable communities are inclusive and therefore, are viewed as places where people want to live and work in, both in the present and in the future. The inclusivity in this case would entail the favourable environment that the city creates and fosters for the people to experience said growth. Therefore, the guiding power can be seen as the inclusive growth of people within the city.

Finally, all the aspect are combined to create the desirable vision. The double helix of the DNA, a metaphor for the two mutually dependant aspects of growth, was chosen as the symbol to represent the vision.

Figure 3: Vision

4.7 Criteria

The formulation of criteria is useful to evaluate the progresses toward the vision from the three different perspectives of sustainability: environmental, social and economical. The chosen criteria and the related indicators are presented in table 1.

Table 1: Criteria and indicators

Criteria	Indicator
Available housing	- Number of temporary houses - Housing shortage (deficiency, balance, surplus)
Affordable housing	- House-price-to-income ratio - Rent-price-to-income ratio
Comfortable housing	Living space per person [person/m2]
Energy-efficient housing	Delivered energy demand of the house [kWh/m2]
Integration factor	Surveys

Availability of housing is one of the most important criteria in the housing sector. This is examined by two indicators: number of temporary housings and housing shortage. As mentioned, Skellefteå is building temporary houses for the fast-growing population (SkellefteåKommun 2021e). However, the long-term aim is to not have residents living in temporary houses, which is why the first indicator was chosen. In addition, the housing shortage indicator is used to achieve a more holistic view of the availability of housing. Sweden measures the shortage of municipalities by giving them a rating in three different categories: deficiency, balance or surplus (Armelius 2022). Currently, Skellefteå has a deficiency of houses, thus by monitoring this rate, the success of the possible solutions can be examined.

The second criterion is *affordable housing*. This criterion provides information about whether there are enough affordable houses available in Skellefteå, which also relates to the inclusiveness of the housing market, reflecting both social and economic perspectives. The indicators that quantify the criterion are the house-price-to-income ratio and the rent-price-to-income ratio. With numeric values of indicators, the suitability of proposed solutions can be valued and compared (Boverket 2009; OECD 2021).

To achieve a holistic view of the housing sector, a criterion of *comfortable housing* is included, which reflects the quality of housing. The indicator chosen is living space per person (persons/m2) (Boverket 2009). This criterion is connected to all three perspectives of sustainability, as the size of the living space can be seen as a trade-off between sustainability and comfortability. Larger houses require more energy to build and often have higher energy consumption than smaller houses with same base conditions. In addition, this indicator could also reflect the social norms; for example, preference for co-living (StatisticsSweden 2020; OECD 2021).

The fourth criterion is *energy-efficient housing*, which is measured by indicator: delivered energy demand of the house in kWh/m2 (EuropeanCommission n.d.). With this criterion environmental friendliness of the houses can be investigated, as it considers factors such as insulation and self-produced energy. This is also an important criterion to measure, as Sweden and the EU have high environmental goals for the housing sector, which were mentioned in Section 4.1 (EuropeanCommission 2022; Eriksson 2008).

The last criterion, the *integration factor*, is related to the social perspective. The aim is to examine how the different solutions in the housing sector succeed in the integration of new people in Skellefteå. This is a criteria that is difficult to quantify empirically. A survey is used, based on a literature review by Laurentsyeva and Venturini (2017). The survey's details can be seen in table 2. The questions would be the same for Skellefteå, but the second one would be modified to concern Skellefteå municipality. The surveys reflect the social and the economic perspective of integration.

This survey could also be executed for the current inhabitants of Skellefteå, therefore the difference between their responses and the ones of new residents would give valuable additional information on the success of integration.

Table 2: Survey questions based on a literature review by Laurentsyeva and Venturini (2017).

Category	Questions
Employed	Employed, self employed or not in paid work?
Self-identification	Do you feel close to the country? *Skellefteå municipality
Social activities	Do you take part in social activities (compared to others of the same age)?
Language usage	Language most often spoken at home, first mentioned
Feeling discriminated	Feeling discriminated
Active citizen	Participation in any civil or political activities during the last 12 months

4.8 Drivers analysis

Although the geographical boundary of the study is Skellefteå municipality, it is important to note that they are not acting in a vacuum. Events occurring outside the system, so called external forces, can and will influence the system in a multitude of ways. Identifying some of these forces and analyzing their potential impact on the studied system is therefor an important part in the backcasting process. One way of doing this is through a so called impact-uncertainty analysis. Each force is assessed based on its potential impact on the system as well as the likelihood of it occurring in the future. Forces with high impact and low uncertainty are labeled ”trends”, whereas forces with high impact and high uncertainty are labeled ”key uncertainties” and are used later on. Any forces with a low impact can be disregarded moving forward in the process (Kordas et al. n.d.[c]).

Figure 4 shows the result of a brainstorming and data collection process in an attempt to identify some forces. Scearce, Fulton, and GBN (2014) show that social, technological, political, environmental, and economical forces all play a part, and it was therefore crucial to identify some forces within each of these realms. The process of deciding the impact/uncertainty of each force was made through discussion and consensus building, as well as using the impact-uncertainty figure in UKMinistryOfDefense (n.d.) that shared some of the forces identified in the brainstorming session.

Based on this figure, two key uncertainties were chosen that would constitute the basis for the futures plane. The point of the futures plane is to identify four different possible futures, that differ depending on the development in the key uncertainty areas. The key uncertainties should be independent of each other and the polar opposites of each key uncertainty should be identified. The key uncertainties chosen were, artificial intelligence (AI) and global economy, since they were deemed most independent of each other from the found key uncertainties.

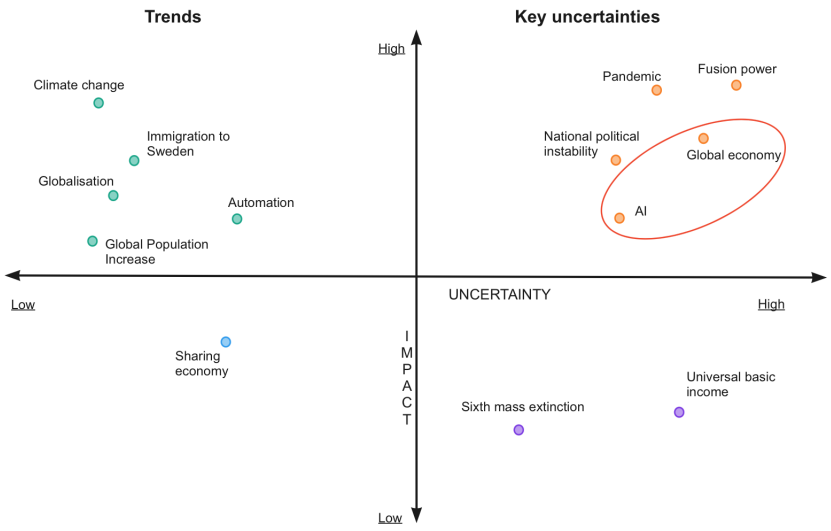

Figure 4: Impact-uncertainty analysis

This resulted in the futures plane visible in figure 5. The trends chosen to analyze in relation to each future are climate change and global population increase.

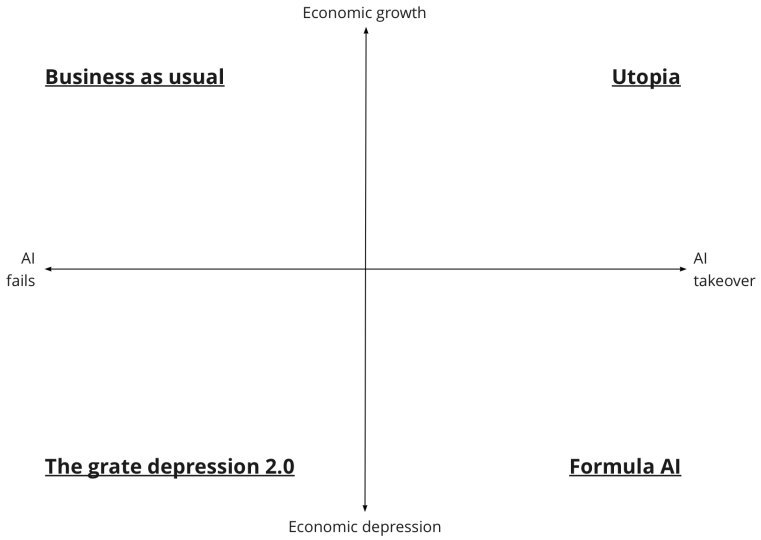

Figure 5: The four possible futures taking AI and Global economy as key uncertainties.

Future 1, *Utopia*, is a future with a strong global economic growth where AI has taken over many of the common jobs today, creating new jobs not familiar to todays' society. Because of the success of AI, the economic growth is perceived to be infallible. The consequences of climate change will likely be less severe than what is currently envisioned with mitigation measures being adopted at a high rate and the population increase will not be a cause for concern.

Future 2, *Business as usual*, is a future where AI development has failed and not been able to change our lives in any significant way. The economy continues to grow anyway, like it has in the

past, and peoples lives continue to incrementally improve. The consequences of climate change will be that of the current trajectory and the population growth will worsen the situation, since more people means higher consumption.

Future 3, *The great depression 2.0* is a future where the world experiences a long lasting economic depression similar to the Great Depression (Romer 2021) and since AI has failed, it has no chance of changing the development. Innovation in societies stagnates and focus is placed on minimizing the damage caused by the economic hardship. Because of this, the consequences of climate change are dire, and society has little to no capacity to adapt. The population growth means that the total volume of suffering is greater.

Future 4, *Formula AI*, is a future where the world suffers from economic depression, and AI has replaced millions of workers, leaving them unemployed. The money in the world are in the hands of the AI companies and the quality of life of the average person has worsened compared to today. It is possible that AI finds a way to mitigate climate change, lessening the consequences of this trend. Because of the economic crisis, the population growth means that more people are living in poverty than ever before.

4.9 Internal scenarios / solutions

The morphological analysis tool, the block method, was implemented to generate solutions regarding the problem under exam. "The block method involves subdividing a system into subsystems and developing a number of scenarios for each subsystem. Scenarios for the initial complex system can then be built as combinations of the scenarios developed for the subsystems" (Pereverza et al. 2017). In the case under study, the terminology used is coherent with Pereverza et al. (ibid.) paper; therefore, the term "subsystem" will be replaced with "dimensions", and the different "states" of a dimension will replace "scenarios for each subsystem".

The dimensions chosen for the socio-technical system under study are:

- construction companies involved,
- types of housing,
- energy utilization,
- types of machines used for construction,
- materials implemented in the building.

These dimensions were identified after considering their possible effect on the housing sector. The type and number of construction companies involved might affect the number of houses built, the quality of construction, the chosen design, and, more in general, the urban planning. The dimensions that might have a possible consequence over the inclusivity factor are the type of houses built and the energy utilization. The latter would also massively influence the environmental impact of the building and would tip the balance in achieving the goal of nearly zero-emissions building. The other two remaining factors, types of machines used for construction and the materials implemented in the building, would also affect the environmental impact of the building and need to be taken into account when implementing life-cycle thinking.

A morphological table (ibid.), was created to present all states of the different dimensions.

Table 3: Morphological table

Dimensions	States of dimension		
Construction companies involved	Monopoly	Municipality	Multiple competitors
Type of housing	Rental	Owned	Co-living
Energy utilization	Traditional	Energy communities	Peer-to-peer networks
Machines for construction	Hybrid machines	Run on electricity	Run on biofuels
Materials	Cement	Wood	Hemp concrete or other innovative materials

As for the dimensions, their different states were identified after brainstorming and data collection. All states of dimensions present both drawbacks and advantages. Monopoly was suggested because it traditionally benefits the companies that have it, as it can raise prices and reduce services without consequence. However, it is a disadvantage for the consumers because there is no fair competition to encourage lower prices or better-quality offerings (MasterClass 2021). Consequently, it was also decided to present a different perspective presenting multiple competitors. On the other hand, municipal housing companies could present some advantages for the tenants, such as countering housing segregation and increasing integration in the municipality itself (F. P. Hüfner and Lundsgaard 2007).

While the difference between rental or owned houses can be easily spotted, co-living was included as a state of the dimension for its innovative aspect. The possible advantage of the co-living product is that it makes it easier and more accessible to live with other people. It also removes ownership and reduces the personal expenses to live. In addition, co-living reinforces a sense of community due to the necessity of sharing space (Drobnis 2018).

Energy communities and peer-to-peer networks were also chosen thanks to their innovative nature. These solutions have the potential to provide flexibility to the electricity system and increase public acceptance of renewables. At the same time, they can directly affect the citizens in a positive way by increasing energy efficiency and lowering their electricity bills (EuropeanCommission 2020; IRENA 2020).

When implementing life-cycle thinking, both the machines used for construction and the material implemented are crucial. The states of these two dimensions were chosen based both on the current state of the art and innovative but current niche ideas (Wang et al. 2016).

Since the morphological approach is suggested to be helpful to explore possible futures systematically (Pereverza et al. 2017), the step that followed the creation of the morphological table was to identify the possible different solutions.

In order to distinguish the three different possible futures a name and a color was assigned for each of them, as shown in Fig 6.

Solution A (orange): monopoly, owned houses, traditional energy utilization systems, machines for construction that run on biofuels and cement as material used.

Solution B (green): municipal housing companies, rental houses, energy communities, hybrid

Dimensions	States of dimensions		
Construction companies involved	Monopoly	Municipality	Multiple competitors
Type of housing	Rental	Owned	Co-living
Energy utilization	Traditional	Energy communities	Peer-to-peer networks
Machines for construction	Hybrid machines	Run on electricity	Run on biofuels
Materials	Cement	Wood	Hemp concrete or other innovative material

Figure 6: Morphological table after selecting three different futures.

machines and hemp concrete or other innovative material.

Solution C (purple): multiple competitors, co-living, peer-to-peer networks, machines for construction that run on electricity and wood as material used.

Each of these futures has both advantages and disadvantages that will be analyzed thanks to criteria evaluation.

4.10 Scenario testing

As the name suggests, this module delves into the testing of the proposed solutions that were presented in the previous module. A multi-level test will be carried out with the first level entailing testing the internal scenarios alongside the criteria that were defined. Moving on from that test, the next level tests the robustness of the proposed solutions. This is done to ensure that the solutions that are being proposed align with the future vision that has been defined. Furthermore, the testing of robustness is undertaken to understand how well the proposed solutions can cope with variations (both known/predictable and unknown/unpredictable) in the futures planes that have also been defined. The term ‘coping’ in this case would ideally entail minimal loss of functionality in said future planes. With the basis of the solution testing established, an incremental approach to the testing shall be followed to provide clarity on the motivation and rationale. The first step of the testing would be the criteria evaluation.

The criteria have already been detailed in Section 4.7 and now its comparison to the proposed

scenarios will be considered. The rating of 1 to 5 that is placed for each part of the table will be motivated as follows.

Criteria	Solution A	Solution B	Solution C
Available housing	4	3	5
Affordable housing	2	3	4
Comfortable housing	4	3	4
Energy efficient housing	2	5	4
Integration factor	3	5	5
Average	3	3.8	4.4

Figure 7: Solutions are evaluated based on the criteria.

All the ratings were given based on sourced information. However, it should be noted that the weightage given to the aspects being considered were decided via a group consensus.

Available housing – According to F. Hüfner and Lundsgaard (2007), houses on a public rental (municipal housing – Solution B) has a lower market share in comparison to private rentals or owner-occupied houses. This means that, municipal housing would be rated lower in comparison to monopolies (Solution A) and multiple competitors (Solution C). Now onto comparing Solution A and Solution C – in terms of Monopoly and multiple competitor housing – based on work of Yang and Liu (2014), it is seen that developers that are in a situation wherein they have high monopolistic power results in less elastic housing supply. This effectively means that the rating of the Solution A would be lower than that of Solution C.

Affordable housing – According to Bresnahan (1982), multiple competitors (Solution C) will tend to have prices that are at least on par with competitive prices but cannot be higher than the monopoly (Solution A) price. Also, Solution C uses wood as the construction material which is cheaper than concrete (GiatecScientific 2020). Furthermore, with regards to the machines used in Solution C, it's more expensive to buy electric construction equipment, compared to conventional machines (Sisson 2022). However, since electric construction vehicles are less noisy, they are permitted to work longer hours (ibid.), which means that construction can finish quicker. This in turn means that less money is spent on workers' salaries which then means that house prices can be reduced further whilst still maintaining appropriate margins. Therefore, an assumption is made that the increased price of the machines is balanced out by the speed of completion. Looking further into the construction aspect of Solution A, wherein machines that run on bio fuels are used shows that since bio fuels are more expensive compared to conventional petroleum diesel (ConsumersReport 2014), the affordability will be lowered for Solution A. Now with regards to municipal housing, based on F. Hüfner and Lundsgaard (2007), is more readily available to all in the sense that there is no means-testing - which is the determination of whether or not people should be eligible for Governmental support. However, Hemp is the material used for Solution B which has been seen

to be more expensive than concrete (Lynch 2020). Furthermore, Solution B uses Hybrid Machines for construction which are not as expensive as fully electric, but not as cheap as conventional machines (Shale-Hester 2021), but since they are not fully electric they cannot be used after hours for construction due to the noise constraints. Therefore, the municipal housing option (Solution B) would get a lower rating rating in terms of affordability, with multiple competitor based housing (Solution C) leading the ratings and with Monopoly housing being the least rated.

Comfortable housing – With regards to Solution B, according to F. Hüfner and Lundsgaard (2007), municipal housing policy focuses raising the average housing standard. From this it can be inferred that extra comfort and amenities are not the main priority which could be the case for the other Solutions.

Energy efficient housing – Based on tests carried out by Evrard and De Herde (2005), the thermal effusivities of the hemp concrete (Solution B), wood (Solution C) and concrete (Solution A) can be seen. The thermal effusivity of hemp = 320 J/m²Ks, of wood = 350 J/m²Ks, of concrete = 1700 J/m²Ks. Hemp in comparison to wood and concrete has a lower thermal effusivity value. This lower value is what leads to buildings made with hemp material providing the most energy efficient housing, since it causes the building to lose heat slower compared to the others (Materion n.d.). Therefore, less energy is required in heating (Increased Energy Efficiency). Therefore, solution B is rated a 5, with Solution C being rated a 4 and Solution A with a 2.

Integration factor – With regards to the integration factor, Solution B is rated the highest because as seen by F. Hüfner and Lundsgaard (2007), municipal housing policy has been tailored to counter housing segregation. This is not necessarily the case for houses that are built in Solution A (monopolies) and Solution C (multiple competitors) since these are solutions that are still carried out by companies that are, as explained by Avelino and Wittmayer (2016), characterized as private and for-profit. The 'for-profit' is an indication of where the focus would lie in comparison with municipal housing. With regards to the rating difference between solution A and solution C, the fact that Solution C opts for a co-living approach and an energy utilization method of peer-to-peer energy trading is what causes it to have a higher rating. These contribute to the integration factor because the process of sharing assets rather than owning them, places more focus on the community (Rinne 2015). From the table it is clear that Solution C has the highest average score, as compared to Solution A and Solution B.

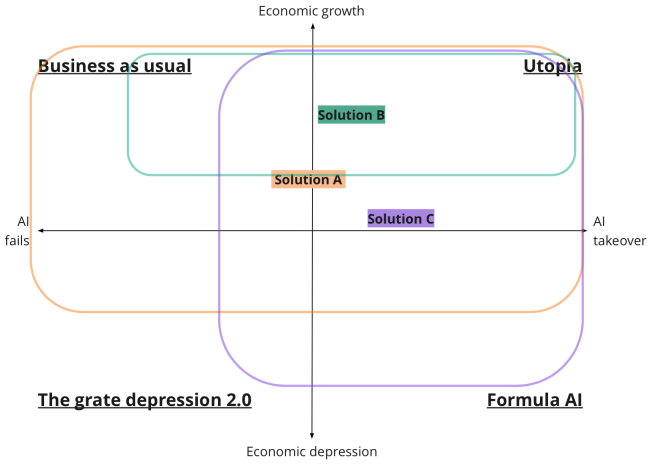

Figure 8: Robustness testing

For robustness testing each internal solution was tested against each of the four external futures. The robustness of a solution is proportional to the area that particular solution covers of that future. From the robustness test the following has been observed. Solution A covers the largest area, followed by Solution C and then Solution B. However, even though Solution A covers a vast area, based on the criteria evaluation it received quite a low score and in terms of innovation - based on a consensus – proved to be very low. Therefore, based on the criteria evaluation and the robustness test area, Solution C seems to be the most viable.

4.11 Final combined scenario for implementation

The final combined solution is solution C but with hempcrete added as a material, due to its innovate nature, and the risk of deforestation when wood is required on the scale necessary for Skellefteå.

4.12 Pathway for implementation of the final combined scenario

After deciding the solution, it was crucial to identify the necessary changes. In order to have a clear idea of the timeline, it was decided to create three different table according to the type of change: cultural, structural or institutional, and technological. Each table presents two or three stages and the suggested steps to achieve the desirable future vision by means of the chosen solution.

Cultural changes	
1st stage from 2022	• Events held by the municipality together with Skellefteå Kraft for raising the public awareness concerning energy efficiency/energy use. • Public debate in the city with participation of all important stakeholders (Nothvolt, municipality and consumers, and Skellefteå Kraft) on peer-to-peer networks and how it positively influence energy efficiency • Information campaign from municipality regarding co-living and peer-to-peer networks • Meeting hub between current citizens and people who have recently moved in, arranged by the municipality • Focus group meeting with relevant stakeholders and people who are moving in to understand needs • Municipality organizing events for people who have recently moved in from outside of Sweden.
2nd stage after 2030	• Develop city as hub for innovations, involving innovative companies in the city, requires broad stakeholder cooperation • Promoting learning regarding the different experiments implemented in the city • Promoting co-living houses for students and new citizens, the university and municipality

Figure 9: Cultural changes (change of people's mindsets, value priorities, learning/unlearning, etc.) (Kordas et al. n.d.[a]).

Structural and institutional changes	
1st stage from 2022	• Municipality incentivizing the adoption of co-living, adoption of newer technologies • Providing citizens with transparent and complete information about electricity consumption, Skellefteå kraft • Protocol for assessment of housing efficiency, Municipality • Skellefteå kraft investigate how co-operation with peer to peer will work • Collaboration between university and municipality, investigate possibilities for co-living for students
2nd stage after 2030	• Energy audit of buildings by municipality, done by municipality or out-sourced consultant. • Strict energy efficiency requirements for housing set in place for procurement, municipality • Policy that all construction of buildings must be done by electrical machines, municipality • Overview of old buildings in municipality, consider rebuilding
3rd stage after 2050	• All buildings must be positive energy houses

Figure 10: Structural and institutional changes (new policies, niche growth through bottom-up initiatives etc.) (Kordas et al. n.d.[a]).

Technological changes	
1st stage from 2022	• Studies and pilot project on hemp concrete and other innovative material • Pilot peer-to-peer project with the creation of online market place for peer-to-peer network • Collaboration with relevant stakeholders (es. Northvolt) for feasibility studies regarding construction machines that run on electricity • Pilot project regarding electrical construction machines
2nd stage after 2030	• Testing of new energy technologies that can connect to housing. Small modular reactors? Small windfarms? Tidal power? Skellefteå kraft • Implementation of renewables (solar PV panels, geothermal heat pump, electrical storage) in buildings to facilitate peer-to-peer network. Skellefteå kraft • Installation of batteries in housing. Skellefteå kraft

Figure 11: Technological changes (new infrastructures, dismantling old infrastructures) (Kordas et al. n.d.[a]).

4.13 Follow-ups: portfolio of 5 experiments

The most suitable solution has been investigated on a theoretical level, therefore, to expand the perspective to a more practical level, five different urban experimentation are designed. The experiments are designed to test the dimensions of the combined solution: peer-to-peer energy system, co-living, wood and hemp as construction material and electrical construction machines. Therefore, the experiments give diverse and important information of the feasibility of the solution.

As stated Section 4.12, the first stage is to create a pilot project on peer-to-peer energy system. This experiment focuses on a particular neighborhood that requires buildings with renewable generation, such as solar, and the creation of an online marketplace. The marketplace would be a platform where the prosumers can sell electricity and other prosumers and consumers can buy it. Skellefteå Kraft and the municipality politicians are important stakeholders connected to this experiment as policies about the trading of electricity only for the neighbourhood is needed. In addition, Northvolt could be asked to join this experiment by providing storage. The experiment is two years long with a one-year milestone. When the milestone is reached, it is investigated if the system could be further optimized to increase energy efficiency and profitability. After two years the result has

to be evaluated to develop an understanding of whether the peer-to-peer energy system should be continued. Therefore, the aim of this experiment would be to understand the reduced energy usage and profitability from the network. Furthermore, a successful outcome could lead to an extension of the peer-to-peer system to cover half or even the whole city, and the possibility of independency from an external grid.

Co-living is the focus in the second experiment. This experiment requires one building with co-living spaces and people willing to live there. Collaborations with university campus in Skellefteå and Northvolt could be executed to attract people to move to the co-living building. As a part of this experiment, university students' awareness about the possibility of co-living is to be increased and they are provided an opportunity to live 1 year in co-living spaces. Northvolt can also provide homes for their employees in co-living spaces. The aim of this experiment is to understand how integration is achieved in co-living, effects on mental health and general attitude for the city, which can be evaluated by creating surveys for the residents. In the future, the cooperation with Campus Skellefteå can be continued and collaborations can be done with other companies in Skellefteå.

The next two experiments, hemp concrete and wood assessment, are closely connected to each other. These experiments require purchasing of the material and construction of one apartment building using hempcrete in one experiment and wood in another one. Multiple construction companies are to be involved to get a broad point of view. The outcomes of these experiments gives valuable information of what is the cost to build such buildings, the time it takes to build, as well as what the energy efficiency of these buildings are. After the experiments, the life-cycle costing and life cycle analysis of concrete and wood are to be compared to expand the information of the advantages and the disadvantages of these construction materials.

The last experiment focuses on electrical construction machines. In this experiment one villa is built using these machines. The aim is to involve Northvolt to collaborate with their battery technology and cooperate with multiple construction companies to achieve comprehensive assessment of the electrical construction machines. With the outcome of this experiment, feasibility of electrical construction machines can be compared to conventional ones. These comparisons would include parameters such as speed and cost. This experiment gives information on how these machines can be utilized in future projects.

Significant factor in all these experiments is the supporting structure. It ensures that experiments are carried out correctly, they are monitored, and the information obtained from them is utilized. The supporting structure in these experiments is going to be a department created in the municipality. Thus, the one department oversees all these experiments and can utilize the knowledge from the experiments and combine and compare them to achieve an optimal solution. The department should include individual from different background to get diverse points of views. There should be citizens that are representatives of Skellefteå, and other stakeholders such as Northvolt and construction companies in order to understand their needs. Furthermore, the department would benefit from including post graduate students (and other experts) who could evaluate the different experiments. Furthermore, there could be innovators from abroad involved in collaboration with (local) entrepreneurs to manage experiments.

5 Discussion and Conclusions

In this section the results will be discussed giving a reflection regarding the implemented method and highlighting the limitations of the proposed solution. Finally, a conclusion will be drawn.

5.1 Reflection from mPB

The first step of the mPB was the problem orientation and prior to meeting with the group, every member was asked to individually come up with problems they feel might be key to target in Skellefteå. The points were brought to the first seminar and discussed with other members. The team at this stage grouped all the individual ideas under the pillars of sustainability – Economical, Environmental and Social. The following areas were identified:

- Energy Increase
- Transport
- Housing
- Societal Integration

It was clear that the focus was very broad, however, since there were some initial doubts as to how broad or narrow the scope was to be, a decision was reached to go ahead with the next step, establishing the system boundaries. At this stage there was clarity on what boundaries to set since the approach was relatively straightforward – Scale, Timeframe and Actors involved. The actors to be involved was chosen according to the initial problem orientation – Municipality politicians, Citizens, Northvolt, Boliden and Skellefteå Kraft.

The current situation analysis was carried out quite smoothly because of the Q&A session with Skellefteå Kommun (Gustaf and Petter) as well as the abundant information available online. What worked well to the teams' advantage was that other groups with a similar focus asked questions that provided an overall picture of the current situation. After the QA, further reading was done as a group through some municipal information which provided further clarity.

For the stakeholder analysis, the work was carried out in such a way that each member of the group analysed a particular stakeholder

Moving on from there, the needs and functions were to be determined and analysed. Keeping in line with the process, the following three needs were identified: Societal Integration, More Buildings, and Energy Increase. Transport was not considered in order to narrow down the focus. The team deployed the WHY Technique, wherein the team was required to question why each of these challenges needed to be solved. Following that, a strategic risk was to be listed as a follow up to the WHY question.

After that was done, When the time came to determine the vision, the team gravitated towards the fact that the growth of the city is a key aspect. Since this was a vision for the year 2050, the duration of the vision brought to light another aspect of growth which the people who are going to be in Skellefteå will experience as well. The Criteria was also done at around the same time and entailed the team brainstorming different criteria that was to be used as a standard which something can be measured against. There were a few key points that were shortlisted and placed, which were thought to be criteria. The reason this has been mentioned is that, whilst progress was being made there was a growing concern amongst the team, regarding the broadness of the aspects being targeted. Which is why, when the Driver Analysis rolled around, the team realized that what was listed in the previous module were actually indicators and not criteria. There was feedback provided which still was not fully clear to the team. After revising the criteria, progress of the Driver analysis was aided by the crowdsourcing exercise that made the process a lot smoother. When it came to the futures

plane, the key uncertainties highlighted were Migration and Political Co-operation.

In fairness, due to the proximity to the Interim presentation the team decided to pay more attention to the preparation for the interim presentation and not to the solutions module. This worked well in the end because the Interim presentation provided some much-needed insights. At this point the doubts that were present concerning the broadness of the topic came to a full boil and the confusion made itself evident during the presentation. The feedback handed to the team gave some much needed clarity on the focus topic. Which is why, the moment the Interim presentation was completed, a major overhaul was required. After taking a couple of days to allow the feedback to sink in, the team met and decided to track back all the way to Module 1 and then restart the steps, however this time the focus would be purely on the housing sector. Although there was initial hesitation to restart all the way from the beginning, the renewed focus enabled the steps to be redone at a much faster rate and with much better clarity.

The actors involved changed slightly, Boliden was removed and construction companies and the University campus were added. The system boundaries also remained the same. With regards to the current situation the narrowing down ensured that only the situation pertaining to the housing sector remained. A similar approach was used for the Needs and Functions. The future vision remained the same. The criteria required quite the overhaul and this time rather than listing indicators, criteria were listed. With this renewed clarity, there was a change in the driver analysis as now the key uncertainties that were used to make the futures plane was changed to economic stability and the influence of AI. Moving on from this point was relatively smooth, since now that the criteria had been corrected, the creation of the morphological table was a much smoother process, and the consensus-based grading was done. After this, the robustness testing was done and made a lot more sense to the team since where exactly the focus needed to be placed was crystal clear.

The fact that the team restarted the steps all the way from the beginning did mean that there was always a lag with what was currently being carried out in the seminars, however, morale was high since corrections were implemented before it was too late. It was at this point that the reality struck that had the topic continued to remain as broad as it was, it would be virtually impossible to carry on with the final few modules.

Once it came to the pathway, since the progress of the steps was refined, it made the creation of the pathway significantly easier. The linkages between the action plan and follow up required some literature reviewing by the team which took a day or two. But it was possible to complete all of the steps with the report being carried out simultaneously.

5.2 Limitations and recommendations for further exploration

This project is based on the modular participatory backcasting framework, wherein a core aspect is the active involvement of relevant stakeholders. However, since the stakeholder participation was limited, this resulted in a less informed study than would be considered ideal. In addition, the limited time for this project restricted the possibility of extensive research on chosen innovations. This in turn limited the certainty of the viability of the solution. Another limiting factor was the language barrier. Only one member of the group is from Sweden and most of text about Skellefteå was in Swedish. Furthermore, due to the remote location of Skellefteå a visit to the municipality was not possible. A study visit could have given insight into the challenges that different stakeholders of Skellefteå face.

The proposed solution includes multiple collaborations. However, it is uncertain whether the cooperation can happen in reality. The chosen criteria and robustness testing scenarios includes

limited number of variables that was chosen to provide knowledge of the suitable solution. In reality, the most significant variables that affect the outcome can be different. Furthermore, the economic feasibility of the solution was not a priority. Lastly, the recommended solution is based on the expectation that the population of Skellefteå will increase. In a scenario where the growth of Skellefteå does not correspond to the forecast, the proposed solution might not be fully feasible.

It is recommended that research on chosen technologies, electric construction machines, peer-to-peer networks and hemp concrete, is executed to achieve more knowledge of the disadvantages and advantages. Additionally, the recommended five experiments should be implemented, especially focusing on the economic viability aspect. The stakeholders' interest to collaborate should be also inquired to have a clear aspect on the possibilities of cooperation. As mentioned, the aspects that were considered are limiting thus expanding the point of view should be done to achieve a more holistic view of the solution.

5.3 Conclusions

In conclusion, Skellefteå is facing a challenging housing situation in the short term, as was observed in the current situation and the needs and functions modules. The proposed solution is a market with multiple competitors building co-living spaces using machines run on electricity. The material used for building constructions is wood or hempcrete, and the co-living spaces are connected to a peer-to-peer network that runs on renewable electricity. This solution aims to provide an innovative yet feasible way to help realize the desirable future. The key stakeholders were identified as citizens, the municipality, Northvolt, Campus Skellefteå, and construction companies. Their respective interest and power in the housing sector were analyzed.

Furthermore, the vision, *Skellefteå 2050, an inclusive city that sustainably grows with you*, created a clear idea of what the desirable future was meant to be. Multiple solutions and different ways of testing them were also identified. Solution C with hempcrete provided the most all-encompassing solution that involved a good balance between innovation and practicality. Furthermore, the pathways - that dealt with technological, cultural and institutional changes - and the five proposed experiments ensured a logical sequence of steps that could be followed to fully realize the future.

6 Reflections on teamwork

The team consisted of 4 members, Alice Scalamandrè (Smart Cities, Italy), Erik Bojo (Sustainable Technology, Sweden), Jeremy Gideon (Smart Cities, UAE) and Seela Tervo (Renewable Energy, Finland). The diversity in cultures and academic expertise determined the organisation of the team to an extent. Erik and Seela being from the Nordic regions were responsible for finding the right public information for the project. Alice was delegated the responsibility of exploring private stakeholders (Northvolt, Construction Companies). Gideon was assigned to the analysis of citizens and their roles in the social sustainability aspects.

With regards to the project management, all decisions were purely made on a consensus basis, whether it was the number of meetings to have or to the work that was to be allocated. The primary mode of communication was a Whatsapp group, and majority of the work took place on the personalized Miro space. Moving onto the phases, during the initial phases of the project there was an emphasis placed on meeting in person since the group believed that it proved to be more effective especially considering the fact that all members were still getting used to working with each other. The positive group dynamics experienced led to increasing the frequency of in person meetings (twice per week), with the online medium utilized only if the possibility of meeting in person was not feasible. Towards the end of the project, the frequency of meetings was increased to approximately 3 meetings a week. The meetings were used to discuss the mPB modules using the manual as well as the group Miro board. Furthermore, at the end of every meeting sections for the report that were to be completed were delegated to team members. If any section seemed too intensive for one person, another member always volunteered to contribute in order to reduce the burden.

Onto the final presentation preparations, brainstorming was done and once again the final deliverable was determined via a consensus. Each member of the group had certain key skills that contributed to the execution of the final deliverable – Alice (video editing), Seela (animation), Erik (vocals) and Gideon (sourcing footage) - however the result was realized only because all members were able to complement one another's skillset and strategically formulate an action plan.

The consensus-based model enabled the team to progress whether situations seemed good or bad, since the team was able to understand when to push forward and when to take a step back and re-evaluate.

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